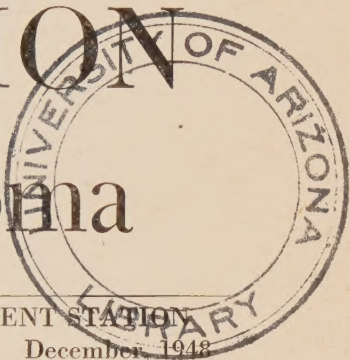


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IRRIGATION for Oklahoma



OKLAHOMA AGRICULTURAL EXPERIMENT STATION
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OKLAHOMA AGRICULTURAL EXPERIMENT STATION

Oklahoma A. and M. College, Stillwater

W. L. BLIZZARD, *Director*

LOUIS E. HAWKINS, *Vice Director*

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IRRIGATION FOR OKLAHOMA

Some Points to Consider.

What Experiment Station Research Has Shown.

Description of Research Now Under Way.

The increasing number of questions on irrigation received by the Experiment Station shows that interest in this subject is growing rapidly in Oklahoma. This circular was prepared to help answer such inquiries. It summarizes results of irrigation research already completed by the Station, and describes current work on the subject. It also suggests some of the things to be considered when deciding whether to irrigate.

No effort is made in this publication to give a complete, detailed description of how to irrigate. Such information is already available elsewhere. Some of the sources of additional information are suggested on page 27.

IRRIGATION in most of Oklahoma is a matter of having water available at critical stages in plant growth. There are times when a few days of dry weather can mean the difference between a good crop and a poor one, but we seldom need to depend on irrigation for ALL of the moisture needed by a crop.

One or two irrigations at the right time can give great increases in yield—sometimes double or more. This has been shown by the research summarized on pages 14 to 17. But these same tests also showed that under other conditions there was no increase in yield, and sometimes an actual decrease. Irrigation water cannot be substituted for soil fertility, for an agreeable temperature, nor for good cultural practices.

The question of whether to install irrigation facilities demands some knowledge of the quantity of water required, of how to use a limited amount of water effectively, and of the soil to be irrigated.

THIS PUBLICATION WAS COMPILED in the Experiment Station Editorial Office from information furnished by members of the Station's research staff and others. Those who provided research data and general information, reviewed the manuscript, or otherwise aided especially in its preparation include: H. B. Cordner, Horticulturist (Vegetables); Frank B. Cross, Head, Horticulture Department; Henry Dunlavy, Agronomist (Cotton); Horace J. Harper, Soils Scientist; Louis E. Hawkins, Vice Director; the Oklahoma Geological Survey; the Panhandle A. & M. College (Milton England and Raymond Peck); and E. W. Schroeder, Head, Agricultural Engineering Department.

In those parts of Oklahoma where supplemental irrigation water is most needed to prevent crop failure, the hazards of soil conditions and water quality are greatest. These problems can be overcome. But their existence is a warning that large-scale irrigation is not to be undertaken without careful investigation.

SOME GENERAL CONSIDERATIONS

Water

The amount and kind of water available is naturally of first importance in deciding whether irrigation is possible. There is no quick, easy answer. The percentage of salt and other chemicals a water can contain and still be safe for irrigation depends on the soil texture and drainage as well as on the kinds of minerals in the water. The amount of water needed varies with the time of year when rains normally fall, the kinds of crops to be grown, and soil differences. Most irrigation systems are planned to wet the soil to a depth of 10 inches to a foot at each application. As an average, this takes 2 acre inches of water—less in sand and more in a tight soil. The sand will need more frequent irrigation than the tight soil.

Much of the past and current irrigation research of the Oklahoma Station is related to the problem of getting the most benefit from the least water. This research is summarized on page 18.

Soil

The larger yields of irrigated crops mean they are taking more plant food out of the soil. Therefore the soil must be naturally fertile, or be properly fertilized and supplied with organic matter. However, the larger yields with irrigation often make it profitable to use fertilizer when it would be uneconomical without irrigation.

"Do not think for a moment that water turned on a crop means a full crop, with no further attention. On the other hand, irrigated soils require the best cultivation, care and management, if they are to repay you for the extra trouble."—Irrigation for Oklahoma, Oklahoma Agricultural Experiment Station Bulletin No. 18, published in 1896.

"IRRIGATION:—Irrigation to supplement natural rainfall could be used in many sections of the State to increase yields or insure a crop, but cost of production under irrigation must be given consideration. Irrigation from surface water supplies is possible at scattered locations throughout the State. Irrigation using ground water could be developed in the High Plains area, but should not be widely attempted until test drillings have located adequate supplies and indicated their safe rate of sustained use. Suitable spacing of wells and controlled use of water probably will be necessary for safe development.

"In any irrigation project, both the soil and the water must be adapted to such use. Also to be considered is the effect of upstream reservoirs in maintaining or reducing flow available for irrigation use." Looking Forward in Oklahoma Agriculture, Oklahoma Agricultural Experiment Station Bulletin No. B-299, published in June, 1946.

The soil must also have proper texture and sub-soil drainage. Some fine-textured soils are not porous enough to let the water soak in. A tight subsoil may prevent satisfactory drainage and thus speed up the accumulation of harmful salts in the surface soil. Some soils are too sandy for anything except sprinkler irrigation. Where artificial drainage is needed in addition to irrigation channels or spray lines, the cost of installation is greatly increased.

Slope of the soil not only affects the cost of preparing land for irrigation, but also the kind of irrigation method to be used.

Crops

Crops grown on irrigated land must be those which make a good income per acre, in order to repay the cost of irrigation and show a profit. A market must be available for the types of crops that can be irrigated.

The variety, as well as the type of crop, must be adapted to growth under irrigation. Varieties which do well under rather dry conditions often do not make the best yields when irrigated (See Page 21).

Cost

Cost of installation and operation must be balanced against probable increase of income. Irrigation takes extra labor as well as larger investment and greater cost of upkeep.

"Know-how"

"Know-how" gained by experience is as important to success in irrigation as it is to any other undertaking. Even persons with long experience in irrigated farming find they must depend to some extent on "cut an dry" methods when they start irrigating a new piece of ground.

ALTERNATIVES TO IRRIGATION

Alternatives to irrigation might well be thought about before making a final decision to install irrigation facilities. New information on how to adjust cropping practices to the available soil moisture is becoming available (See list of publications, page 27). Consideration of this information may in some cases lead to a decision that the cost of irrigation is not warranted. On the other hand, of course, it might be decided that the types of crops grown could be changed to take advantage of irrigation.

On some land there will be no alternative. Preliminary investigation will show that irrigation is impossible, due to slope, soil or water conditions. On such land the possibilities offered by shifting the cropping plan from year to year to take advantage of whatever soil moisture is available will be of special interest.

PRELIMINARY PLANNING

The information given here can be used to decide whether it might be practical to install an irrigation system at a particular location. But, before investing in equipment or preparing land, it would be wise to have final plans for the system designed by an engineer, preferably someone experienced in irrigation layouts.

The information needed to plan and design a satisfactory irrigation system includes:

1. Water supply—

- (a) Quality.

- (b) Quantity and rate available.

- (c) Distance water level is below land to be irrigated, including drawn down if the source is a well.
2. Acreage to be irrigated.
 3. Distance from water supply to land to be irrigated.
 4. Soil type, including subsoil.
 5. Slope of land.
 6. Crops to be grown.
 7. A sketch or map showing area to be irrigated including slope of land and location of water supply. A topographical map is preferred.

Water to be used for irrigation must be free of salts harmful to plant growth. To determine whether the available water is suitable for irrigation, a sample should be sent to a laboratory to be tested. Such tests, and advice on the suitability of the water for irrigation, may be had by sending a sample to the Oklahoma Agricultural Experiment Station.*

The first step in planning an irrigation system is to decide whether water is to be put on by sprinkler or by surface application. Careful planning and study are usually necessary to decide which is best for a particular set of conditions. In some cases, the decision may be based on personal choice, depending upon labor, management, and previous experience. Furrow irrigation requires constant attention. Spray lines may operate without attention for from two to six hours at a time, but some labor is required to move the pipes in a portable spray system.

There are many variations in each method. The sprinkler system may be either portable or a permanent installation. Surface applications may be made by furrows, corrugations, or the border and flooding method. The various types of installations are described in more detail in the Farmers' Bulletins list on page 27. Oklahoma research comparing the two methods is further discussed on page 22.

Sprinkler System

A sprinkler system may be used under practically all conditions if properly designed and laid out. However, tall row crops such as corn may require special designs and layouts. It is also possi-

* Write a letter telling what you want to know about the water and attach it to the package containing the sample. Put first class postage on the letter and parcel postage on the package. If package and letter are mailed separately, the analysis and reply are likely to be delayed.

ble that some crops may give better yields with other methods of irrigation.

If topography and soil are adapted to surface application of water, the sprinkler system is likely to be more expensive both in first cost and in operation. But the sprinkler system will be found especially adapted when:

- (1) The land is too rough and irregular or too shallow to permit leveling.
- (2) Soils are too porous or slopes too steep for surface application, or
- (3) The water supply is limited.

WATER REQUIRED

If the irrigation system is operated 24 hours a day, 6 gallons of water a minute will be needed for every acre irrigated. This is equivalent to two inches of water per acre per week. If the irrigation system is operated only 8 hours a day, 18 gallons of water a minute will be needed for every acre irrigated. Therefore to irrigate 40 acres working only 8 hours a day the source of water must supply 40×18 or 720 gallons a minute, and the pump must be able to handle that amount of water at the desired pressure.

POWER REQUIRED

A method is given below for estimating the number of horsepower needed to operate a water pump for a sprinkler irrigation system. This method is not accurate enough to be the basis for an actual installation, but it will help check on whether a sprinkler system would be practical. The actual horsepower needed by a specific installation must also include enough power to overcome the friction of water in the pipes, which takes more force than the person untrained in engineering might believe.

The steps in estimating the minimum power needed to drive a pump for sprinkler irrigation are:

- (1) Find out how high the field to be irrigated is above the water level from which the water is to be pumped (including draw down if the source is a well).
- (2) Multiply pounds of pressure needed to operate the system by 2.3.

- (3) Add the figures obtained in steps (1) and (2).
- (4) Multiply Sum of (1) and (2) by the number of gallons of water needed per minute.
- (5) Divide product in (4) by 2,000.

The answer obtained in (5) is the number of horsepower needed to drive pump, assuming a pump efficiency of 50%.

For example, to find the horsepower needed for a pump supplying 720 gallons a minute at 40 pounds pressure from a well 100 feet deep (after draw down).

- (1) Height of field above water level is 100 feet.
- (2) Multiplying 40 (pounds pressure) by 2.3 gives 92.
- (3) Adding (1) and (2) is $100+92=192$.
- (4) Multiplying by 720 (gallons per minute) is $720 \times 192 = 138,240$.
- (5) Dividing by 2,000 is $138,240 \div 2,000 = 69.12$.

The 69.12 is the horsepower needed, theoretically, BUT this estimate of horsepower does not take into account friction in pipes. That depends upon (a) size of pipe and (b) distance the water has to be pumped along the surface of the ground.

Surface Irrigation

Surface irrigation is better adapted to land that has:

(1) A regular slope of less than three or four feet per hundred, in one direction.

(2) A rather "tight" soil. If soils are too open and sandy, considerable water may be lost by sinking below the level of plant roots.

(3) A soil deep enough to permit the necessary leveling.

Surface irrigation takes more water than sprinkler irrigation, because the area where the water enters the border strip or furrows get more than does the other end of the field.

A quick preliminary check on the feasibility of a proposed surface irrigation system can be made by estimating the water and power needed. But *it is highly important that careful surveys and plans be made before laying out the system.* Experiments show that rows or borders that are too long or do not have enough slope may increase use of water by 75 to 100 percent. In other words, they may waste up to half the water applied. Wasteful use of water by surface methods of application may also result from putting the

water on too slowly, or from putting it on a soil that is too open. Border strips or furrows on too steep a slope or too tight a soil may cause erosion. Erosion also can result from applying the water too fast.

WATER REQUIRED

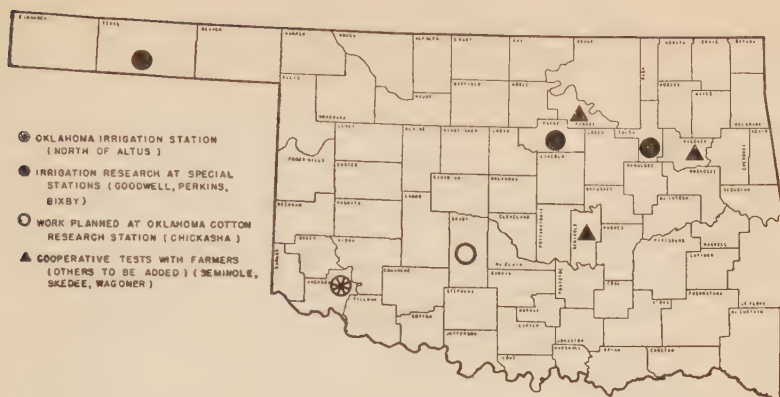
The amount of water needed cannot be estimated as accurately for surface irrigation as it can for the sprinkler method. The amount needed depends upon how fast it is applied, how open or tight the soil is, and the layout of the system (such as slope, and the length of row or border strip). Improper layouts and rates of application may result in using as much as five times the amount of water actually needed.

The usual rates of application for fine textured slowly permeable soils are between 5 and 8 cubic feet per second per acre. However on highly permeable soils it may be necessary to apply water at the rate of 10 to 20 cubic feet per second per acre to avoid excessive loss of water due to deep percolation. The rate of 1 cubic foot per second is about 450 gallons per minute. It follows then that the rate at which water is needed for surface methods of application is 2250 to 9000 gallons per minute for each acre watered at one time depending upon factors discussed in the two preceding paragraphs. Since more water is used where the water enters the border or furrows, even with well designed systems an average of 5 to 10 inches of water over the entire area is needed to get water on the side of the field opposite the water inlet. Therefore applying water at the rate of 8 cubic feet per second per acre requires that the water be allowed to flow from one to two hours to irrigate each plat. This gives a basis for estimating the water needed to irrigate by surface methods.

Example: At what rate is water needed to irrigate 40 acres if the irrigator is willing to work 24 hours per day?

Allowing four hours for time lost closing and opening borders, ditches, gates etc. leaves 20 irrigating hours. Allowing two hours for watering each plat, ten plats could be irrigated in one day. Assuming the 40 acres could be laid out in 80 plats, $\frac{1}{2}$ acre each, it would take 8 days to irrigate the 40 acres watering $\frac{1}{2}$ acre at a time. At the rate of 8 cubic feet per second $8 \times 450 \times \frac{1}{2}$ or 1800 gallons per minute would be required.

To irrigate the 40 acres in eight days working 12 hours per day, would require that the field be laid out in 40 plats, one acre each, or that two $\frac{1}{2}$ acre plats be watered at one time and water



Location of Irrigation Research in Oklahoma.

The major center of irrigation research in Oklahoma is the Oklahoma Irrigation Station north of Altus, where ample water is available from the W. C. Austin Irrigation Project. Chief interest is in methods of applying water, and crop varieties for growth under irrigation. Most of the results will be applicable throughout the State. Other locations deal with special phases of irrigation, such as vegetable production, or growing corn with a minimum of water. The Experiment Station's irrigation research program is described in full on pages 24 to 26.

would be required at a rate of $450 \times 8 \times 1$ or 3600 gallons per minute.

These figures are water rate requirements for well designed and laid out systems on soil types well adapted to surface irrigation, and serve only as an example for preliminary estimate of water requirements. For porous soils or fields not adapted to good layouts 2 or 3 times the water rate indicated may be needed. On coarse open soils it may be necessary that plats be as small as 1/10 acre if surface methods of water application are used.

POWER REQUIRED

No power is needed, naturally, if the source of water is above the land to be irrigated, unless the water is pumped out of a ditch on to the field.

Where water must be pumped, the power needed can be estimated by multiplying the gallons per minute needed by the height the land is above the water source, and then dividing by 2,000. For example, the power needed to apply 1800 gallons per minute on a lying 10 feet above the water level would be $1800 \times 10 \div 2,000$ or 9 horsepower, assuming that the pump used is 50% efficient.

RESULTS OF OKLAHOMA RESEARCH

Effect of Irrigation on Yields

STILLWATER

Vegetables and Cantaloupes

Irrigation tests with vegetables and melons were made from 1938 to 1944, inclusive, at the Station's Perkins farm nine miles south of Stillwater. Table I shows the yields of the irrigated plots, and the percent increase obtained by irrigating.

The yield figures in Table I are for marketable yield. The figures do not include small and below-grade produce. One of the important effects of irrigation is to increase the proportion of salable products.

Strawberries

Hot, dry summer weather is one of the chief enemies of strawberry production in most of Oklahoma. Irrigation is therefore especially valuable on this crop.* In 1943, a total of 13 inches of irrigation water was not enough to prevent some loss of plants in the tests at Stillwater; but two varieties nevertheless made more than 135 crates per acre that year. In 1944, irrigated strawberries of adapted varieties made a profitable crop, but most unirrigated fields were completely killed. Four varieties each produced more than 100 crates per acre under irrigation, and Blakemore made 156 crates.

GOODWELL (PANHANDLE STATION)

The irrigation work at the Oklahoma High Plains Station, Goodwell, is in cooperation with the Panhandle A. & M. College. It was set up primarily to provide feed and food for college use, therefore unirrigated yields were not recorded as they would have been in a strictly research setup. However, the Panhandle college's printed reports** conclude that profitable yield increases were obtained with alfalfa, row crops, and vegetables.

Among the vegetables, the warm season crops such as cucumbers, muskmelons, watermelons, pumpkins, squash and okra can be grown with little difficulty and high yields can be secured by irrigation, the report states. Production of cool-season vegetables such as

* See Okla. Agri. Exp. Sta. Bul. No. B-304, *Strawberry Culture and Varieties*, pp. 21 and 22.

** The Panhandle Bulletin (Panhandle A. & M. College, Goodwell, Okla.) No. 64, "Deep Well Irrigation in the Oklahoma Panhandle" (revised October, 1944); and No. 65, "Vegetables for the Panhandle Area of Oklahoma."

Table 1.—Yields of Marketable Produce per Acre When Irrigated, and Increase in Yield Secured by Applying Water; Perkins Farm, 1938-1944.

Crop, and Unit of Production per Acre	TEST YEAR*							
	1		2		3		4	
	Yield	Percent Increase	Yield	Percent Increase	Yield	Percent Increase	Yield	Percent Increase
Lima beans (60-lb. bu.; dry seed	17.1	102					17.1	102
Snap beans (30-lb. bu.)	174.	544	304.		120.	0**	200.	238
Cantaloupes (50-lb. crate)	495.	186	367.		219.	60	388.	116
Sweet corn (Tons)	5.34	35	3.48		3.76	30		46
Cucumbers (Tons)	18.3	63	9.1				3.71	46
Eggplant (50-lb. crate)	112.	26	364.				13.7	55
Mango peppers (50-lb. crate)	84.	318	176.		380.	262	238.	43
Irish potatoes (60-lb. bushel)	199.	72	303.		206.	13	213.	238
Tomatoes (Tons)	9.30	24	1.78		4.31	26	223.	73
Cabbage (Tons)	14.12	57					1.56	49
							14.12	57

Crops grown on replicated plots which were given uniform cultural treatment, except for the irrigation applications. Increases shown are for the most effective number of water applications; and where both overhead and furrow irrigation was used, the increases are the averages of the two methods.

* Test years: Lima beans, 1939; snap beans, 1939-41; cantaloupes, 1941-44; sweet corn, 1940-43; cucumbers, 1942-43; eggplant, 1939-40; peppers, 1938-40; Irish potatoes, 1939-42; tomatoes, 1940-43; and cabbage, 1939.

** Rainfall in late May and early June was adequate.

cabbage, peas and spinach was sometimes uncertain because of frost or high winds.

Tomatoes did not set on nor develop during the high temperatures and low humidity of summer, the Panhandle report says, but it adds that high production can be secured by growing adapted varieties under irrigation. Variety tests at Woodward and Stillwater indicate the Porter tomato sets fruit better than others under hot, dry conditions.

TIPTON (SOUTHWEST COTTON STATION)

Irrigation is used at the Southwest Cotton Station near Tipton, Tillman county, to avoid danger of losing experimental strains in dry years. Water is applied only when necessary to insure a good yield of seed for maintaining breeding stock. However, yield records have been kept on irrigated and unirrigated areas (Figure 1). They show that irrigation has definitely resulted in higher yields of both seed and lint. The increases have varied greatly from year to year, however, ranging from less than one-fifth to almost fourfold. Irrigation

LBS. LINT
PER. ACRE

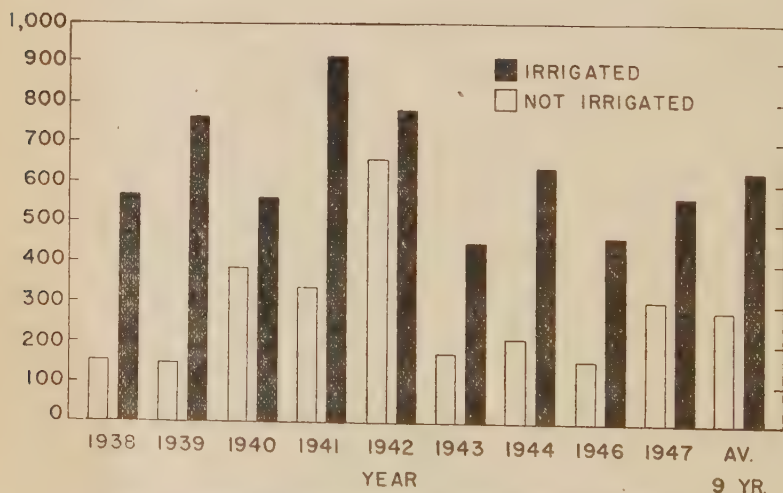


Fig. 1.—Effect of Irrigation on Cotton Yields at Tipton.

Irrigation has more than doubled the average yield of cotton lint at the Southwestern Oklahoma Cotton Station, Tipton, during the past nine years. Percentage increase has ranged from less than 17 percent in 1942 to 333—almost a four-fold increase in yield—in 1939.

gation on a commercial basis might not have been profitable in some years—for example, in 1942, when unirrigated cotton yielded about a bale and a third per acre.

BIXBY (VEGETABLE RESEARCH STATION)

The good showing made by irrigation in the Perkins farm tests led to installation of irrigation equipment at the Oklahoma Vegetable Research Station near Bixby at the time that Station was established in 1944. Irrigation at Bixby has been good insurance for all crops. It helps in two ways: (1) By getting a crop planted at the right time despite a dry surface soil; (2) by carrying crops through temporary dry periods.

Experience at Bixby indicates that irrigation probably pays the best dividends on fall crops, because the weather is usually dry at planting time. The added water paid a large dividend in the fall of 1947 on squash, turnips, and green crops. Dry weather held down the average production throughout the truck crop area and created a good market with good prices. Commercial growers in the Arkansas Valley truck area who were able to irrigate also had good crops and a good income from them.

ALTUS (IRRIGATION STATION)

Work at the new Oklahoma Irrigation Experiment Station near Blair in Jackson county is just getting well established. Results will be published and made available at field days as the work progresses.

Two items illustrate the yields obtained in preliminary work. Irrigated potatoes in the spring of 1946 made 45½ bushels per acre as against 18½ bushels unirrigated. When fertilizer was used, the yields were 69½ bushels irrigated and 44½ unirrigated. Sorghums were given two irrigations of approximately two inches each during the summer of 1947 at times when rainfall was deficient. Grain yields for Wheatland milo were 1,120 pounds per acre unirrigated and 2,864 when irrigated. For Martin's Combine milo the yields were 1,494 pounds unirrigated and 2,490 pounds when irrigated.

Irrigation and Soil Fertility

An example of the way irrigation, by increasing yields, also increases the rate at which plant food is taken from the soil was seen

in the tests at Perkins (page 19). This experiment ran for four years. The fifth year all plots were planted to Irish potatoes, un-irrigated and unfertilized. Yield on the plot that had been irrigated for the preceding four years was 125 bushels per acre. On the unirrigated plot it was 134 bushels. The difference of 9 bushels per acre was due to fertility lost in the higher yields on the irrigated plots, despite liberal use of commercial fertilizer on portions of the area during the four-year experimental period.

The relationship between irrigation and use of fertilizer is being studied in several projects recently started by the Experiment Station. None of these has gone far enough to yield definite information. However, a preliminary test with Irish potatoes at the Irrigation Experiment Station in the spring of 1946 is of interest because the effect of irrigation was about equal to that of fertilization. The yield when unirrigated and unfertilized was $18\frac{1}{2}$ bushels per acre. The yield for 500 lbs. of 5-10-5 fertilizer without irrigation was $44\frac{1}{2}$ bushels, and for irrigation without fertilizer it was $45\frac{1}{2}$ bushels. The potatoes receiving both irrigation and fertilizer yielded $69\frac{1}{2}$ bushels per acre.

Time of Applying Water

Irrigation in Oklahoma is a matter of supplementing natural rainfall rather than depending upon artificial watering for the entire moisture needs of a crop. Therefore the problems are somewhat different than they are in desert irrigation. In fact, the average annual rainfall for the area to the east of U. S. Highway 81 (Enid to Waurika) covers almost exactly the same range as is found in the Corn Belt of Illinois 32 to 46 inches a year.* But, as newcomers in Territorial days soon noticed, rainfall throughout Oklahoma is likely to be less dependable than in the states to the east. The problem, then, is one of providing water at times when rainfall is short during a critical period in crop development. A little water at the right time can often mean the difference between a poor crop and a good one.

The Experiment Station from 1940 to 1944 ran a series of experiments at Perkins to find the most effective time for using limited supply of water to best advantage in irrigating vegetable crops. The same type of research is at present being conducted with corn and other field crops in other parts of the State.

* *Climate and Man*. Yearbook of the United States Department of Agriculture, 1941; pp. 850 and 1073.

"A satisfactory distribution of the rainfall is almost as important for successful crop production as is a sufficient annual supply. In this respect Oklahoma is fairly but not entirely fortunate. We have no distinct wet and dry seasons. Generally the principal rainfall occurs during the growing season. On the other hand, drouths during critical periods of crop growth are not uncommon. The total rainfall is sometimes largely made up of excessively violent rains and of very slight showers. Most of the water from the former is lost; that from the latter cannot penetrate the soil to any perceptible depth."—Irrigation for Oklahoma. Oklahoma Agricultural Experiment Station Bulletin No. 18, published in 1896.

VEGETABLE CROPS

In the irrigation tests at Perkins, watering of truck crops gave substantial yield increases even in years when the rainfall was relatively abundant. But these tests also indicated that, where the amount of water available for irrigation was limited, there were certain periods in the growth of the crop when watering did the most good. In general, pre-harvest irrigation gave practically as good yields as irrigation throughout the growing season, as shown in the following reports on specific vegetables.

IRISH POTATOES.—A few irrigations applied to Irish potatoes while the tubers are developing in May and early June frequently means the difference between a good crop and a failure. In the Perkins tests, three or four irrigations during this period resulted in doubling the yield of No. 1 tubers in some years.

Table II.—Effect of Varying Irrigation Treatments in a Season of Irregular Rainfall; Irish Potatoes, Perkins Farm, 1942.*

	Yield of No. 1 Tubers (Bu. per Acre)	Increase From Irrigation	
		Bushels	Percent
Three irrigations; May 19, May 26, and June 1	185	90	95
Two irrigations; May 26 and June 1	151	56	59
One irrigation; May 26	142	47	50
One irrigation; June 1	107	12	13
Not irrigated	95	--	--

* Rainfall for the 1942 potato season was poorly distributed, with an abundance in April, a dry May, and more than average after the May drouth was broken June 6.

Table III.—Comparison of Irrigation on Sweet Corn Before and After Silking; Perkins Farm, 1940.

	Yield of No. 1 Ears (Tons per Acre)	Increase From Irrigation	
		Tons	Percent
Irrigated entire season (seven times)	5.34	1.38	35
Irrigated only after silking	4.98	1.02	26
Irrigated only before silking	4.34	.38	9
Not irrigated	3.96	--	--

The effect of applying water at different times was especially well illustrated in 1942. That year there was abundant rainfall in April, a dry May, and more than average after the May drouth was broken on June 6. Three irrigations nearly doubled the yield (Table II). But even more interesting is the fact that one irrigation May 26 gave a 50 percent increase, while on June 1 was delayed too long and produced only a 13 percent increase in marketable yield.

Recommendations on irrigating potatoes in Oklahoma were published in Oklahoma Station Bulletin B-266 (1943). The research was reported in Technical Bulletin T-18 (1943).

SWEET CORN.—With sweet corn, irrigation was of most value during the time the ears were developing, even though rainfall was more deficient earlier in the season. This is illustrated by the 1940 data in Table III. When corn was irrigated up to silking time, but not thereafter, yield increase was only 9 percent. It was 26 percent when irrigation was started at the time the ears began to silk. Ordinarily, about three irrigations were sufficient to make a good crop.

TOMATOES.—Tomatoes benefited more than other crops from irrigation after harvest started, due to the fact that this crop con-

Table IV.—Effect of Varying Irrigation Treatment on Tomatoes; Perkins Farm, 1940.

	Yield of No. 1 Fruit (Tons per Acre)	Increase From Irrigation	
		Yield	Percent
Irrigated entire season (seven times)	9.3	1.8	24
First irrigation omitted	9.1	1.6	21
Preharvest irrigation only (three times)	8.8	1.3	17
Irrigation only during harvest			
Not irrigated	7.5	--	--

tinues to set fruit after harvest begins. The added water during harvest season kept the foliage up to provide shade for the fruit. Table IV shows the effect of varying irrigation treatments in 1940. Throughout the four-year test, yields were greatly reduced by irregular and light applications of water.

FIELD CROPS

COTTON.—Cotton has been irrigated for nine years at the Southwest Cotton Station at Tipton. Comparison of rainfall records and yields of irrigated and unirrigated cotton during these years suggests that irrigation is most effective in seasons when the April and May rainfall is below normal.

CORN.—Rainfall records indicate that central and eastern Oklahoma usually have enough moisture for corn in May and June, but that growth of this crop is frequently limited by insufficient rain in July. This suggests that a relatively small amount of water in July would produce yields up to what the fertility of the soil could support, and also that fertilizer could be effectively used to increase yields still further. Research aimed at getting detailed information on this relationship between moisture supply and fertilizer for corn in this area is now in its second year.

Crop Varieties for Irrigation

In the tests at Perkins, varieties which made the best yield records in unirrigated variety tests did not always do as well when irrigated. It is probable that more benefit can be obtained from irrigation by planting varieties which respond well to adequate moisture.

At Goodwell, varieties commonly grown in that area have done well when irrigated, but no definite comparisons have been made.

Comparisons of different varieties irrigated and unirrigated are now being worked out for both vegetables and field crops in the research at the Irrigation Experiment Station and elsewhere.

In general, later-maturing varieties are favored by irrigation. The earlier-maturing kinds make a crop before the usual summer "dry spell" occurs. Later varieties are potentially more productive, and with irrigation are able to turn this potential into higher actual yields. An example is shown in results of irrigation tests

Table V.—Effect of Irrigation on Early- and Late-maturing Varieties of Snap Beans; Perkins Farm, Average of 1939 and 1940.
(Bushels per acre)

Variety	Unirrigated	Irrigated	Increase Due to Irrigation	
			Bushels	Percent
Bountiful (early)	83	154	71	86
Refugee No. 5 (late)	43	240	197	455

with snap beans at Perkins in 1939 and 1940. As an average for the two years, irrigation increased the yield of Bountiful, an early variety, only 86 percent as compared to an increase of 455 percent for Refugee No. 5, a late variety (Table V).

Methods of Applying Water

Comparisons of the sprinkler and furrow methods of irrigation were made at the Perkins farm several years ago. More extensive comparisons are now under way elsewhere in the State.

Results at the Perkins farm in 1939 and 1940 are given in Table VI. The advantage for overhead irrigation shown in the work at Perkins led to adoption of this method at the Oklahoma Vegetable Research Station.

The relative cost of equipment and water for the two methods is now being compared at the Irrigation Station in Jackson county. However, the difference in cost is not as great as one might think; the added cost of pipe for overhead spray is at least partly offset by the cost of preparing the land for furrow irrigation.

Portable tripod pipe supports for the spray line were worked out by Station horticulturists during the irrigation tests at Perkins. The spray lines can be moved quickly when these tripods are used in combination with quick-coupling pipes.

Table VI.—Comparison of Overhead and Furrow Irrigation; Perkins Farm, 1939 and 1940.

	Yields (Bushels per Acre)			Advantage of Overhead Over Furrow	
	Not Irrigated	Furrow	Overhead	Bushels	Percent
Snap beans	67	212	225	13	6.1
Irish potatoes	159.5	250	257.5	7.5	3.0
Eggplant	296	361.5	414.5	53	14.9
Peppers	178.5	674	694.5	20.5	3.0

The border "flooding" method was found most satisfactory at the High Plains Station at Goodwell because the land was nearly level.

A planting method was worked out at Goodwell to overcome the poor stands due to formation of a soil crust after gardens are irrigated by furrows at planting time. The essential point is to plant the seed on a ridge between the furrows and carefully hold the water level to a half inch below the crown. This moistens the seed from below without forming a crust above it.

SOURCES OF IRRIGATION WATER

Quality as well as quantity must be considered when deciding if available water is adequate for irrigation. Water containing too high a proportion of minerals is unfit for use on farm land. No general rule can be given, however, because the danger point varies with the kind of minerals in the water, the relative proportions of different minerals (e. g., proportion of calcium to sodium), and the chemical composition and drainage of the soil where the water is to be applied. The composition and quality of the water in Oklahoma streams may change from one week to the next, depending on which part of the watershed contributes most to the flow. This variation is found in the ground water along streams as well as in the actual flow of the stream itself.

The quantity of water must be great enough to thoroughly wet the soil ten inches to a foot deep at each irrigation. In the Station tests at Perkins in 1939 the yield of tomatoes and peppers was greater on the unirrigated plot than it was where these crops received some water but not enough.

The question most often asked about water sources is: "Can I irrigate from my farm pond?" The answer must be, "that depends." Obviously, the amount of land to be irrigated and the size of the pond are important. But other factors such as acreage draining into the pond, plant cover on the drainage area, kind of soil to be irrigated, and crops to be grown are also important.

The Experiment Station's research on effective irrigation with minimum water (see page 18) was done with the idea in mind that ponds might be a source of water. The Station's agricultural engineers are now working on questions concerning size of pond, size of drainage area feeding the pond, etc.

When wells provide irrigation water, the cost of pumping is of course important. It varies with depth of water and cost of available power. The amount of underground water available must also be considered. A supply adequate for irrigating one field might soon dry up if several farms in the immediate vicinity were irrigated. Electric power for pumping irrigation water from a 50-foot well at the Perkins farm averaged about \$1.85 per acre inch of water from 1938 to 1944. Officials of the Panhandle A. & M. College at Goodwell are of the opinion that irrigation from wells will definitely pay in the High Plains area where the cost of natural gas for pumping is low.

Information on water available for irrigation in a particular location in Oklahoma can be obtained from the Oklahoma Geological Survey, Norman, Okla. The water resources of Oklahoma are briefly discussed in Oklahoma Agricultural Experiment Station Bulletin B-229, "Looking Forward in Oklahoma Agriculture," pages 44 to 49.*

THE EXPERIMENT STATION'S IRRIGATION RESEARCH PROGRAM

The Experiment Station now has irrigation research under way at several locations in Oklahoma. One special station, in the Altus-Lugert area, is entirely devoted to research on irrigation problems. Current work is an expansion of studies made at the Perkins farm in 1938-44, supplemented by practical use of irrigation made at the High Plains Station at Goodwell since 1937, the Southwest Cotton Station near Tipton since 1938, and at the Oklahoma Vegetable Research Station near Bixby since 1944. The work at Goodwell, Tipton, and Bixby provides information on the practical operation of irrigation systems under the conditions at these three

* An extensive analysis of the water resources and water problems of Oklahoma, considered as part of the entire Arkansas Valley region, is presented in *Regional Planning, Part XII—Arkansas Valley*, National Resources Planning Board, June, 1943. Available data on the State's water resources as related to industry are presented and discussed in considerable detail in *Oklahoma Water: Quantity, Occurrence, and Quality of Surface and Ground Water*, prepared for the Oklahoma Planning and Resources Board by the United States Department of the Interior, Geological Survey, Water Resources Branch, March 1, 1945. Water data for the State are also summarized in the industrial survey of Oklahoma published in loose-leaf form in 1945 by the Division of Industrial and State Planning of the Oklahoma Planning and Resources Board. Other information concerning the water supplies of the state is given in *Minerals of Oklahoma Map* published by the Oklahoma Geological Survey in 1944; in other publications of the survey; and in *The Chemical Analyses of the Waters of Oklahoma*, Publication No. 52 of the Engineering Experiment Station of the Oklahoma A. & M. College (1942). Climatological data of the State are available in *Climate and Man: Yearbook of the United States Department of Agriculture*; 1941. pp. 1065-1074.

locations. Water at all three locations is supplied by wells. At the new Oklahoma Cotton Research Station near Chickasha, it is planned to irrigate with water from the Washita River, thus giving opportunity to study the problems of irrigation from open streams. Various tests using farm ponds as a source of irrigation water for corn were started in the summer of 1947 and are being expanded during 1948.

The following paragraphs list the irrigation research projects now under way, and indicate the questions expected to be answered by this research. Answers to some of these questions have been worked out in other parts of the United States; and this information is being tested for applicability to Oklahoma conditions.

Engineering Phases of Supplemental Irrigation.

What method of application makes most efficient use of water under Oklahoma conditions?

What equipment is needed for supplemental irrigation from (1) farm reservoirs, (2) wells, and (3) streams?

What is cost of installing irrigation, using water from the three sources named?

How big must a farm pond or reservoir be to provide water for supplemental irrigation?

What method of irrigation is best adapted to various conditions? (Methods to be tested include: Flooding; corrugation; sprinkler; porous hose; subsurface; and various combinations of these.)

Irrigation of Alfalfa.

What effect does irrigation have on seed yield?

How much can hay yields be increased by irrigation, by fertilization without irrigation, and by a combination of water and fertilizer?

Irrigation of Small Grains, Corn, and Sorghums in Southwest Oklahoma.

How does the yield increase obtained by irrigation compare with the increase from use of fertilizer, and what increase can be obtained by a combination of irrigation and fertilization?

Which varieties do best irrigated, when fertilized, and when given both irrigation and fertilizer?

What effect does irrigation have on test weight, lodging, maturity, etc., of small grain?

Irrigation of Cotton.

How often is supplemental irrigation water needed?

How much yield increase can be obtained?

What effect does irrigation have on the quality of fiber produced?

Vegetable Growing Under Irrigation in Southwestern Oklahoma.

What kinds and varieties of vegetables do best when irrigated?

What method of irrigation (furrow or overhead spray) is best for vegetables?

How can irrigated vegetables be protected from damage caused by windblown sand?

How can a home garden be best arranged for irrigation?

Irrigation of Corn in Central Oklahoma.

How much yield increase can be obtained by a combination of irrigation and fertilization, and what is the value of each alone?

What methods can be used to determine when a soil should be watered to prevent drouth injury to plant development?

SOURCES OF ADDITIONAL INFORMATION

The following Farmers' Bulletins of the United States Department of Agriculture are useful general references on methods of irrigation, equipment, etc.:

F. B. 1922 Practical Irrigation.

F. B. 1846 Supplemental Irrigation.

Three other Farmers' Bulletins deal with irrigation of specific crops. They are:

F. B. 1518 Orchard Irrigation.

F. B. 1556 Irrigation of Small Grains.

F. B. 1630 Irrigation Practices in Growing Alfalfa.

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A list of publications relating to irrigation is given in Panhandle A. & M. Bulletin 64 (revised 1944). This bulletin also discusses general aspects of irrigation in the Oklahoma Panhandle, describes the experiences of farmers who have tried irrigation in that area, and gives suggestions based on irrigation done at the Panhandle A. & M. College at Goodwell (Oklahoma High Plains Experiment Station).

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Panhandle A. & M. Bulletin 65 reports experience with irrigated vegetables at the High Plains Station at Goodwell.

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Information about the W. C. Austin Irrigation Project at Altus is available from the Altus office of the U. S. Bureau of Reclamation.

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Information about availability of water for irrigation in various parts of Oklahoma can be obtained from the Oklahoma Geological Survey, Norman, Okla. Some of the information now in print is cited in the footnote on page 24.

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Water samples will be analyzed on request by the Experiment Station. See mailing instructions in footnote on page 9.

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Information about suitability of a particular soil for irrigation can be obtained from the State Soils Laboratory, Agronomy Department, Oklahoma A. & M. College, Stillwater. Before sending samples, write for instructions or see your county agent.

Studies of the relationship between soil moisture and crop yields have been published in the following Oklahoma Agricultural Experiment Station publications:

Cir. C-83, Climatic Conditions and Suggested Cropping Systems for Northwestern Oklahoma.

Bul. B-319, Oklahoma Crops and Soils, 1947; article entitled "Behavior of Summer Fallow Under Varying Seasonal and Climatic Conditions," pp. 142-147.

Cir. C-129, Information for Visitors . . . etc., pp. 9-11.

Some of the basic information used in developing cropping plans adapted to varying soil moisture conditions was published by the Oklahoma Station in the following bulletins:

Bul. B-190, The Utilization of Moisture on Heavy Soils of the Southern Great Plains.

Bul. B-192, Initial Soil Moisture and Crop Yield.

Bul. B-193, Heavy Plains Soil Moisture Problems.

Bul. B-214, Moisture and Fertility Relations of Subsoil Variations in Heavy Silt Loam Soil at Goodwell, Oklahoma.

Bul. B-215, The Economy of Soil Nitrogen Under Semiarid Conditions.

Bul. B-216, Raw Organic Matter Assumulations Under Various Systems of Culture.